Measured Data are Uncertain: So What??

Daren Harmel, PhD

Uncertainty in H/WQ Data

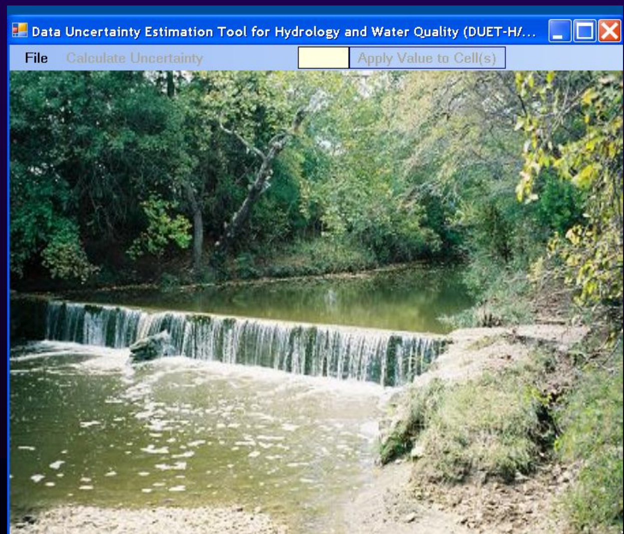
"Should it not be required that every… (field and modeling study)… attempt to evaluate the uncertainty in the results?" Beven (2006)

"The use of uncertainty estimation… (should be)… routine in hydrological and hydraulic science." Pappenberger, Beven (2006)

- Uncertainty in H/WQ data is most often ignored in spite of:
  - Such pleas for uncertainty analysis
  - Fact that all measurements are inherently uncertain.

DUET- H/WQ

- **Developed uncertainty estimation framework (2006)**
  - **focused on Q, TSS, N, and P data for small watersheds**
  - **listed published uncertainty estimates in 4 categories**
    - **discharge, sample collection, preservation/storage, lab analysis**
- **Developed DUET-H/WQ to be more user-friendly (2009)**
  - **added "data processing and management" procedural category**



DUET- H/WQ

- **Uses the RMSE method to determine uncertainty**
  - **contributed by each procedural category**
  - **for individual measured discharge, concentration, load values**

DUET-H/WQ - LookUp Table for calculation of uncertainty in discharge measurement

Select the published value for each step or source of uncertainty

Individual discharge measurement

Individual discharge measurement	Uncertainty	Reference
Direct - area-velocity method - poor conditions	±20%	Sauer and Meyer (1992)
Direct - area-velocity method - average conditions	±6%	Sauer and Meyer (1992)
Direct - area-velocity method - ideal conditions	±2%	Sauer and Meyer (1992)
Direct - area-velocity method - ideal conditions	±2%	Boning (1992)
Direct - area-velocity method - ideal conditions (0.2,0.8d velocity)	±6.1%	Pelletier (1988)
Direct - area-velocity method - ideal conditions (0.6d velocity)	±8.5%	Pelletier (1988)
Manning's equation - Stable, uniform channel; surveyed reach and cross-section; accurate "n" estimate	±15%	Slade (2004)
Manning's equation - Unstable, irregular channel; surveyed reach and cross-section; poor "n" estimate	±35%	Slade (2004)
Direct - area-velocity method	±5% to ±15% (average ±9.3%)	Tillary et al. (2006)

± %

(Click to change)

Continuous discharge measurement

Pre-calibrated flow control structure (properly designed and installed) with periodic meter checks	±5% to ±8%	Slade (2004)
Pre-calibrated flow control structure (properly designed and installed)	±5% to ±10%	Slade (2004)
Stable channel with stable control, 8-12 stage-discharge measurements per year	±10%	Slade (2004)
Shifting channel, 8-12 stage-discharge measurements per year	±20%	Slade (2004)
Natural channel, ideal conditions	±6%	Boning (1992)
Instream velocity meter	----	N/A
OTHER -	---	N/A

± %

(Click to change)

Continuous stage measurement

Float recorder	±2%	Cooper (2005), unpublished data
Float recorder	±3 mm	Hershey (1975)
KPSI series 173 pressure transducer	±0.1%, ±0.022% thermal error	KPSI (2005)
ISCO 730 bubbler flow module	±0.035 ft ±0.0003 * ft * temp. change from 72 deg. F	Teledyne ISCO (2005)
Campbell Scientific SR50-L ultrasonic distance sensor	Larger of ±1 cm or 0.4% of distance to water surface	Campbell Scientific (2003)
OTHER -	---	N/A

± %

(Click to change)

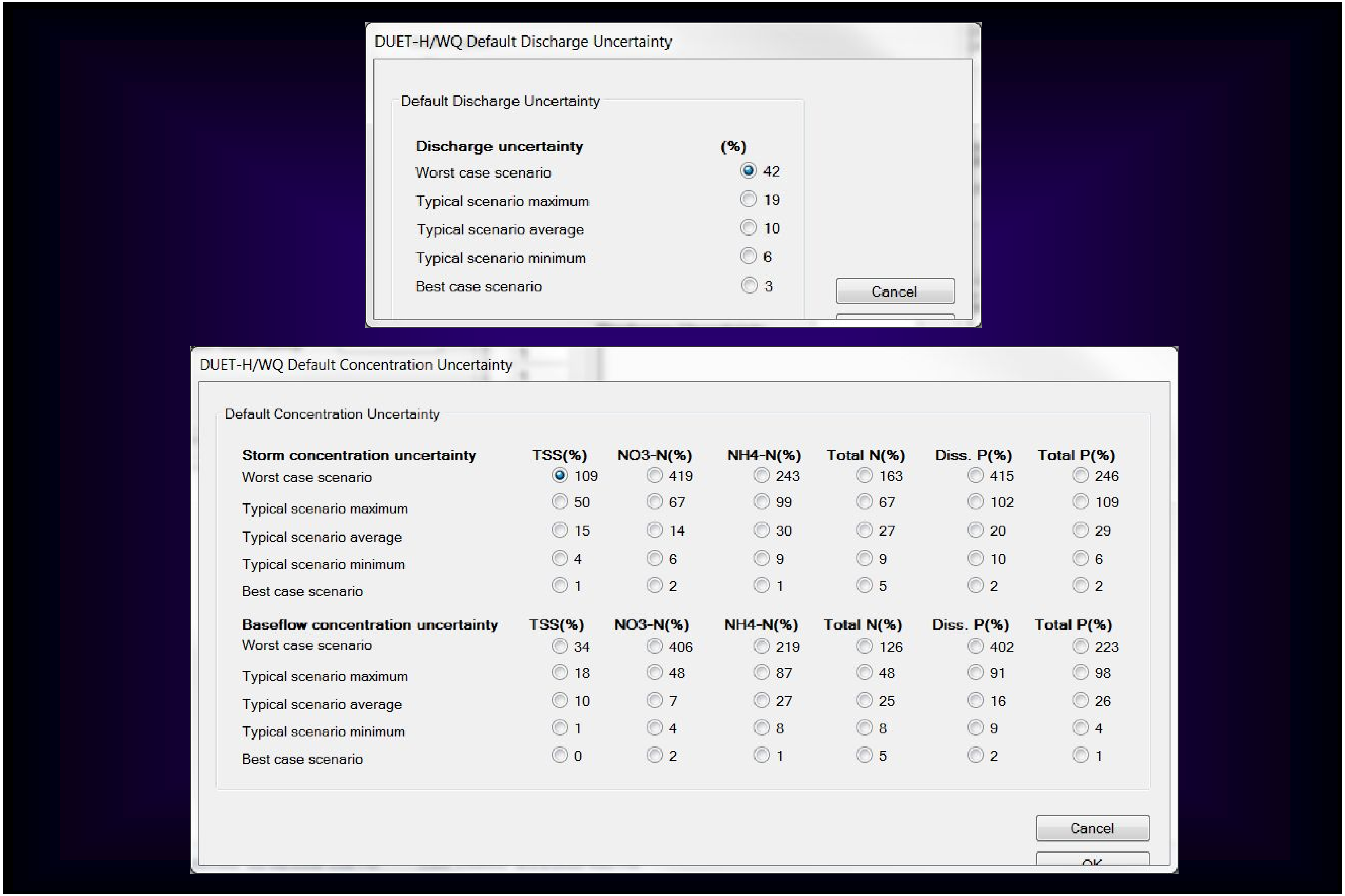
Effect of streambed condition

Stable, firm bed	±0%	Sauer and Meyer (1992)
Mobile, unstable bed	±10%	Sauer and Meyer (1992)
OTHER -	---	N/A

± %

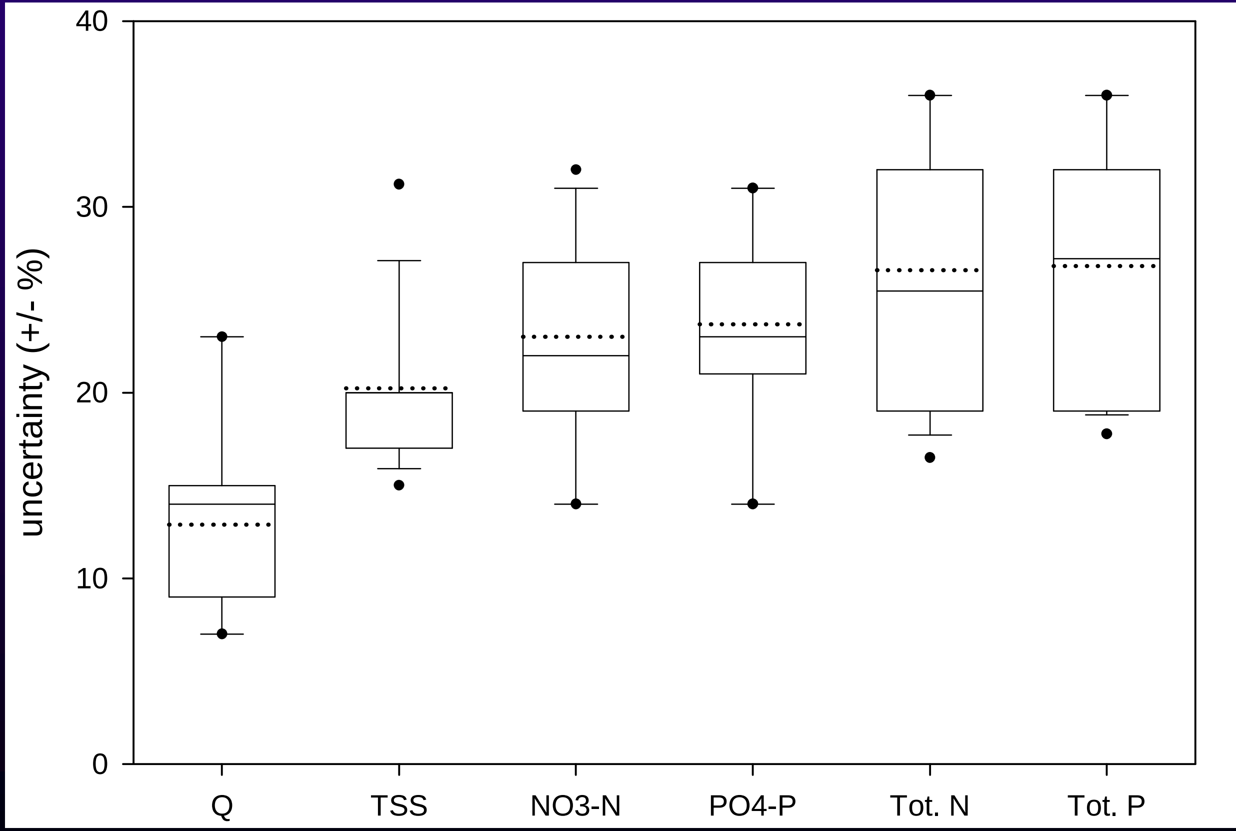
(Click to change)

Cancel


DUET-H/WQ Default Discharge Uncertainty
Default Discharge Uncertainty
Discharge uncertainty (%)
Worst case scenario 42
Typical scenario maximum 19
Typical scenario average 10
Typical scenario minimum 6
Best case scenario 3
Cancel
DUET-H/WQ Default Concentration Uncertainty
Default Concentration Uncertainty
Storm concentration uncertainty TSS(%) NO3-N(%) NH4-N(%) Total N(%) Diss. P(%) Total P(%)
Worst case scenario 109 419 243 163 415 246
Typical scenario maximum 50 67 99 67 102 109
Typical scenario average 15 14 30 27 20 29
Typical scenario minimum 4 6 9 9 10 6
Best case scenario 1 2 1 5 2 2
Baseflow concentration uncertainty TSS(%) NO3-N(%) NH4-N(%) Total N(%) Diss. P(%) Total P(%)
Worst case scenario 34 406 219 126 402 223
Typical scenario maximum 18 48 87 48 91 98
Typical scenario average 10 7 27 25 16 26
Typical scenario minimum 1 4 8 8 9 4
Best case scenario 0 2 1 5 2 1
Cancel

DUET- H/WQ Application

- Applied to real-world data sets from five monitoring projects
  - various hydrologic settings, land uses, watershed sizes, and field and laboratory techniques
  - 131 storm events
- Estimated uncertainty for:
  - Q
  - TSS
  - NO_3-N, PO_4-P
  - total N, total P



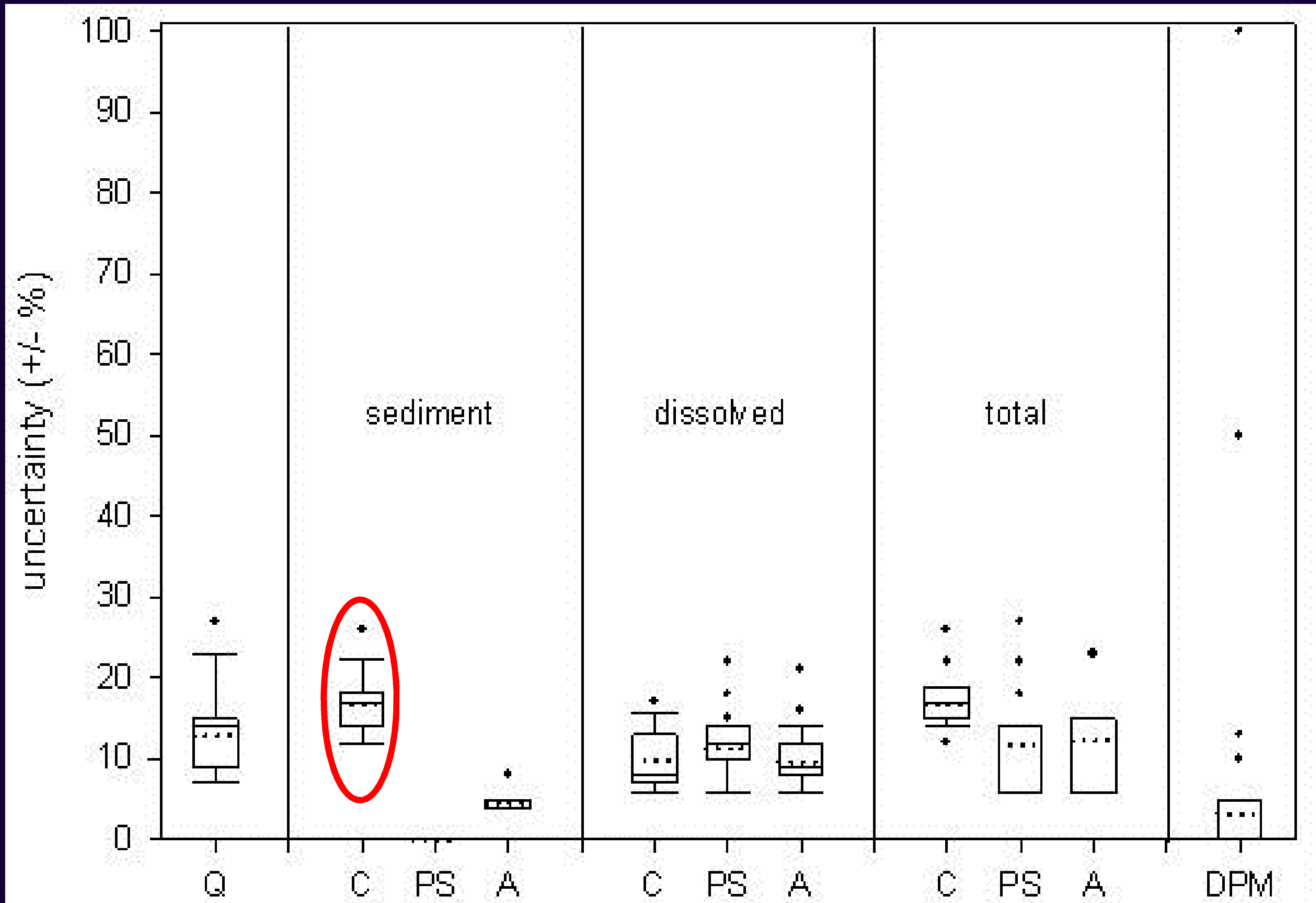
Measured Data are Uncertain:
So What??

- Applies to:
  - Technical staff (laboratory, field, QA/QC)
  - Researchers, modelers
  - Agency personnel, consultants
  - Policy makers, regulators, stakeholders
- Related to:
  - Research and monitoring
  - Data reporting
  - Regulation and policy
  - Model evaluation

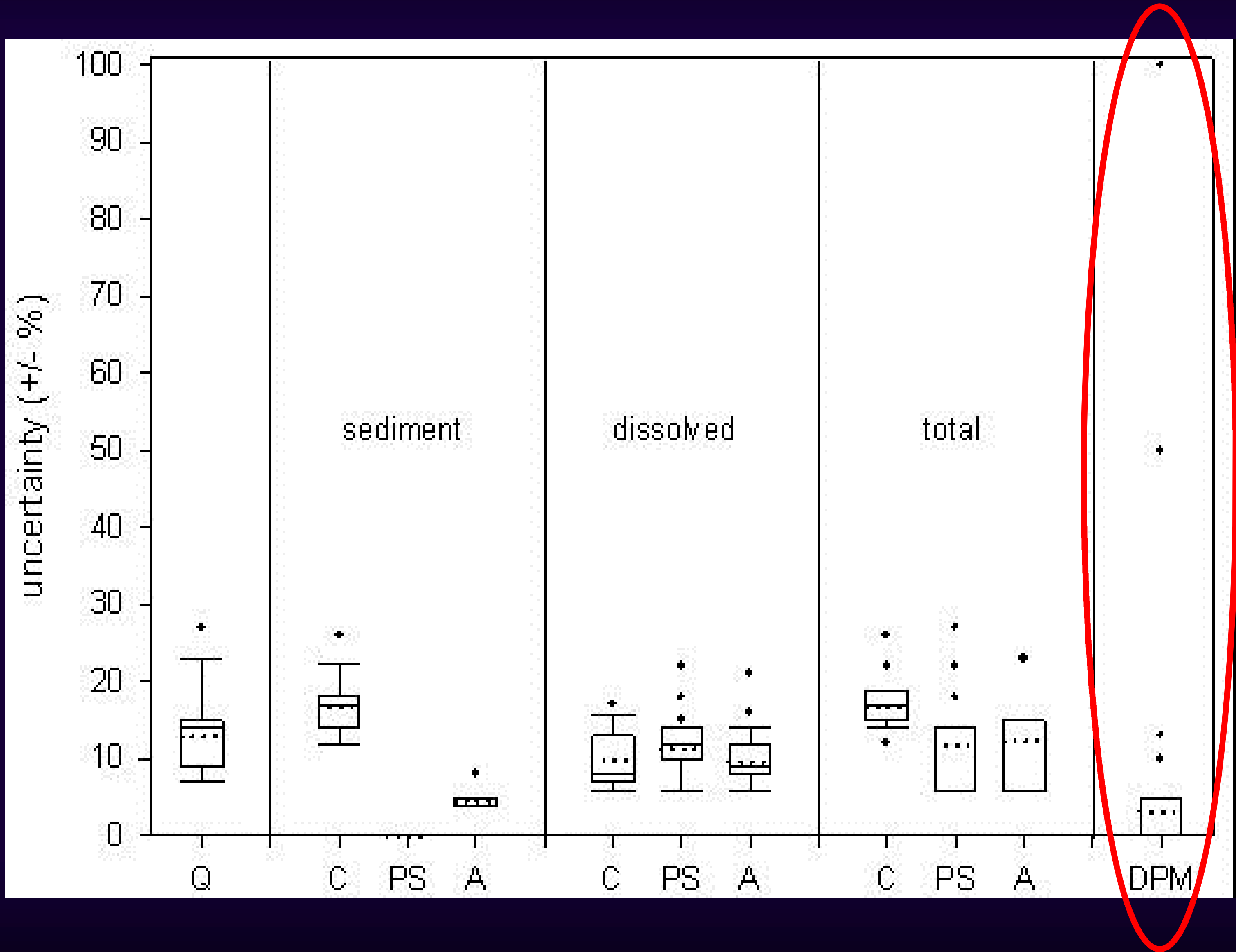
Research and Monitoring

- Difficulties:
  - H/WQ data collection already a difficult task (storm events, remote sites).
  - Disagree about which uncertainty estimation method to use.
- Benefits:
  - Focus QA/QC on steps/procedures with greatest uncertainty.
  - Support training on proper field and laboratory techniques.
  - Balance project resources with data quality concerns.

Research and Monitoring



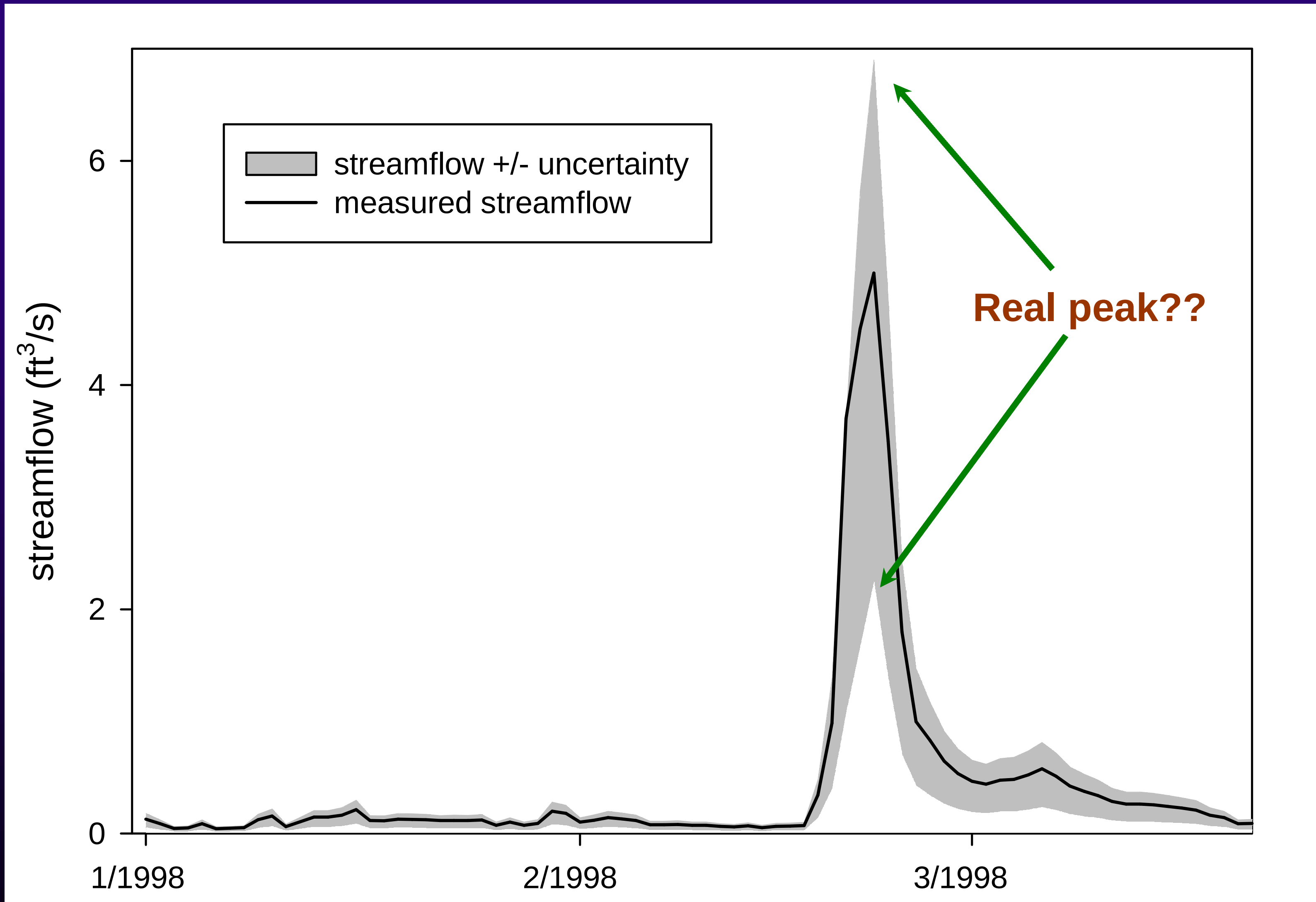
Research and Monitoring



Data Reporting

- Difficulties:
  - Fear of negative perception if report data with “high” uncertainty.
  - Belief that public, stakeholders, elected officials can not understand uncertainty.
- Benefits:
  - Certain value of data with corresponding uncertainty estimates.
  - Scientific integrity - should be honest about what you know and what you don’t know.

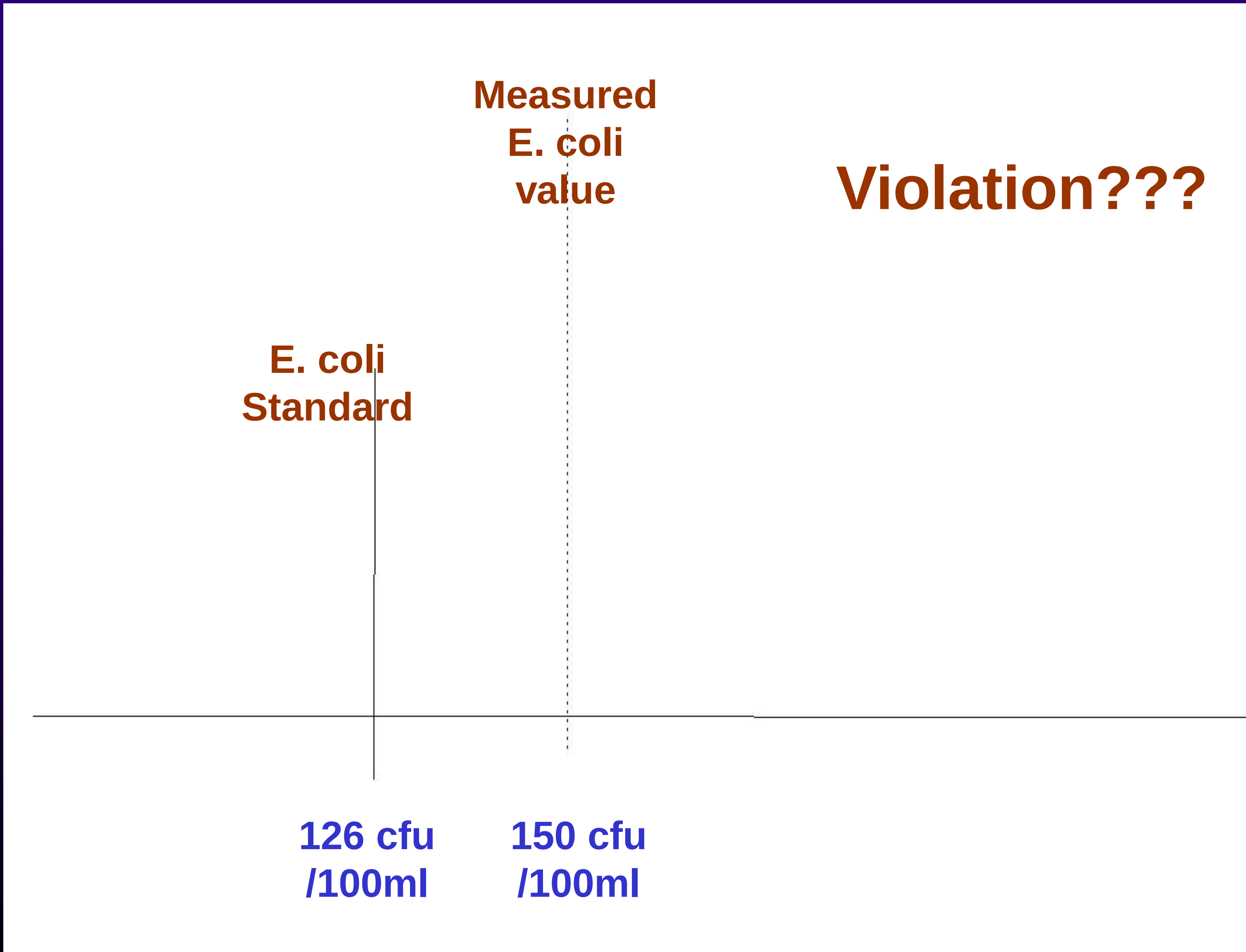
Data Reporting



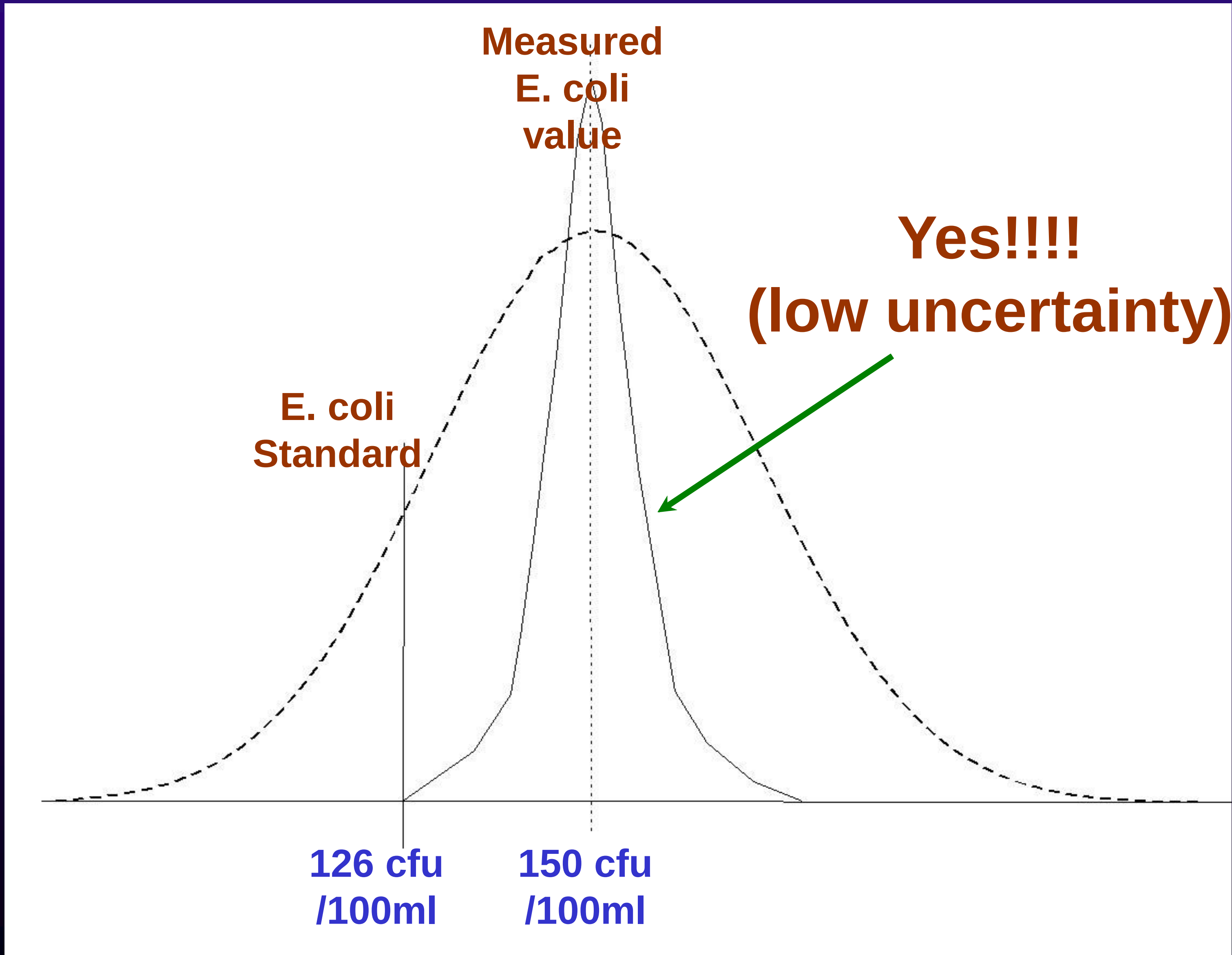
Regulation and Policy

- **Difficulties:**
  - **A great deal of written information competes for readers' attention**
    - **therefore, only briefs/abstracts are typically read.**
  - **Opponents search for weak points to attack unwelcome conclusions and undermine author credibility**
    - **therefore, difficult to appropriately present uncertainty without drawing attention to the inaccuracy of measurements.**
- **Benefits:**
  - **Choose different (more cost-effective) policy or regulatory pathway depending on uncertainty in measured data.**
    - **"low" uncertainty - strict regulation/enforcement may be justified**
    - **"high" uncertainty - adaptive management approach preferred**

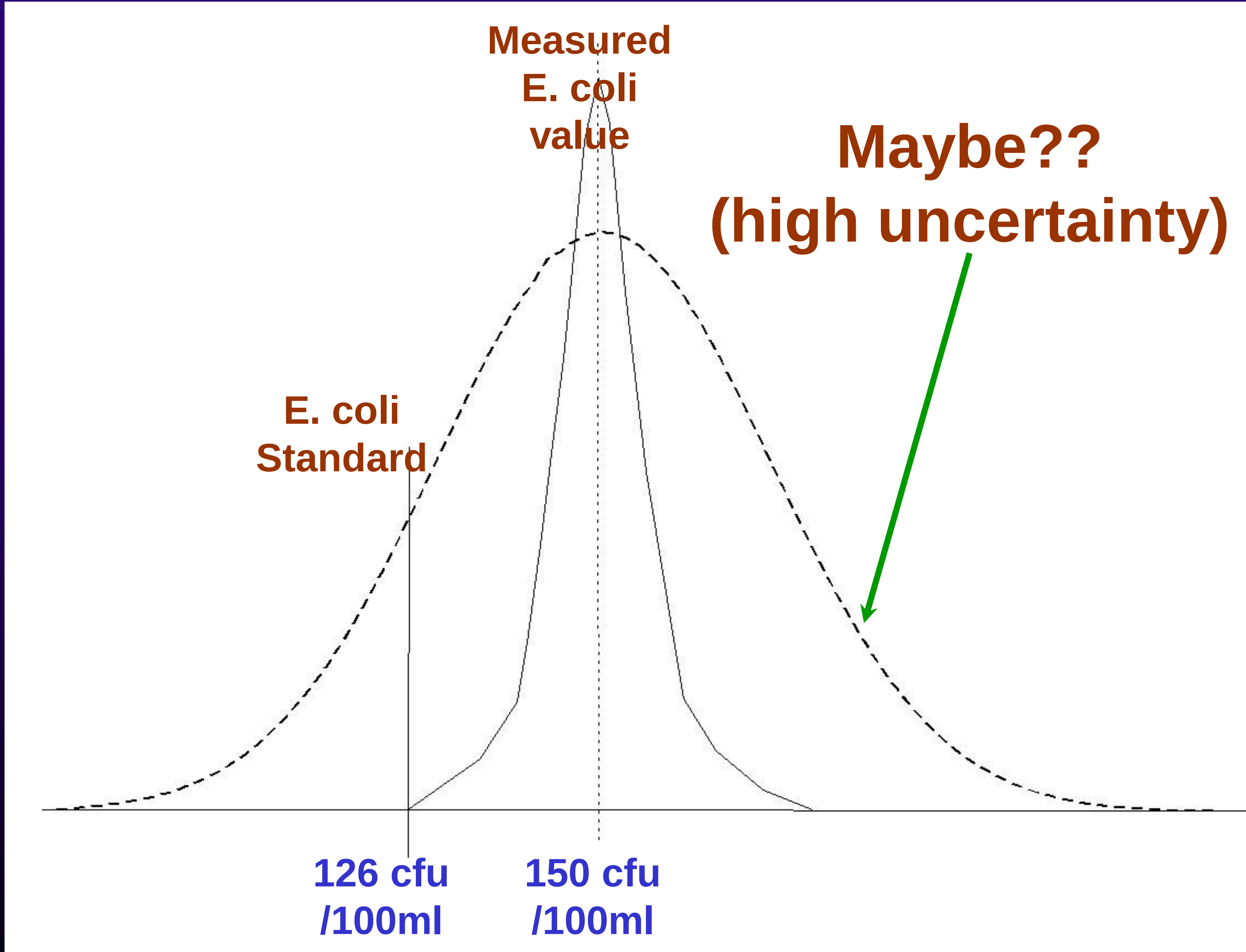
Regulation and Policy



Regulation and Policy



Regulation and Policy

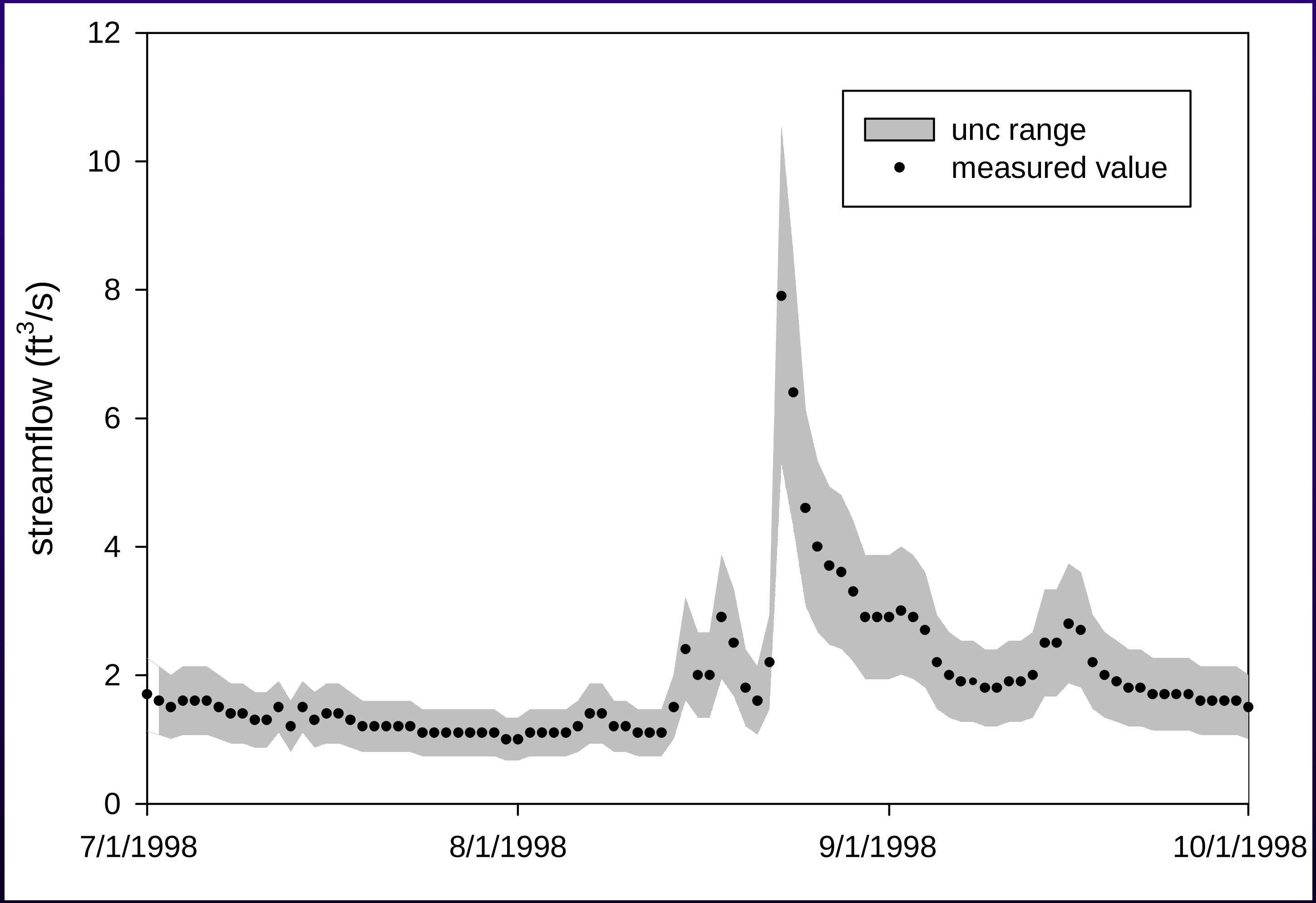


Model Evaluation

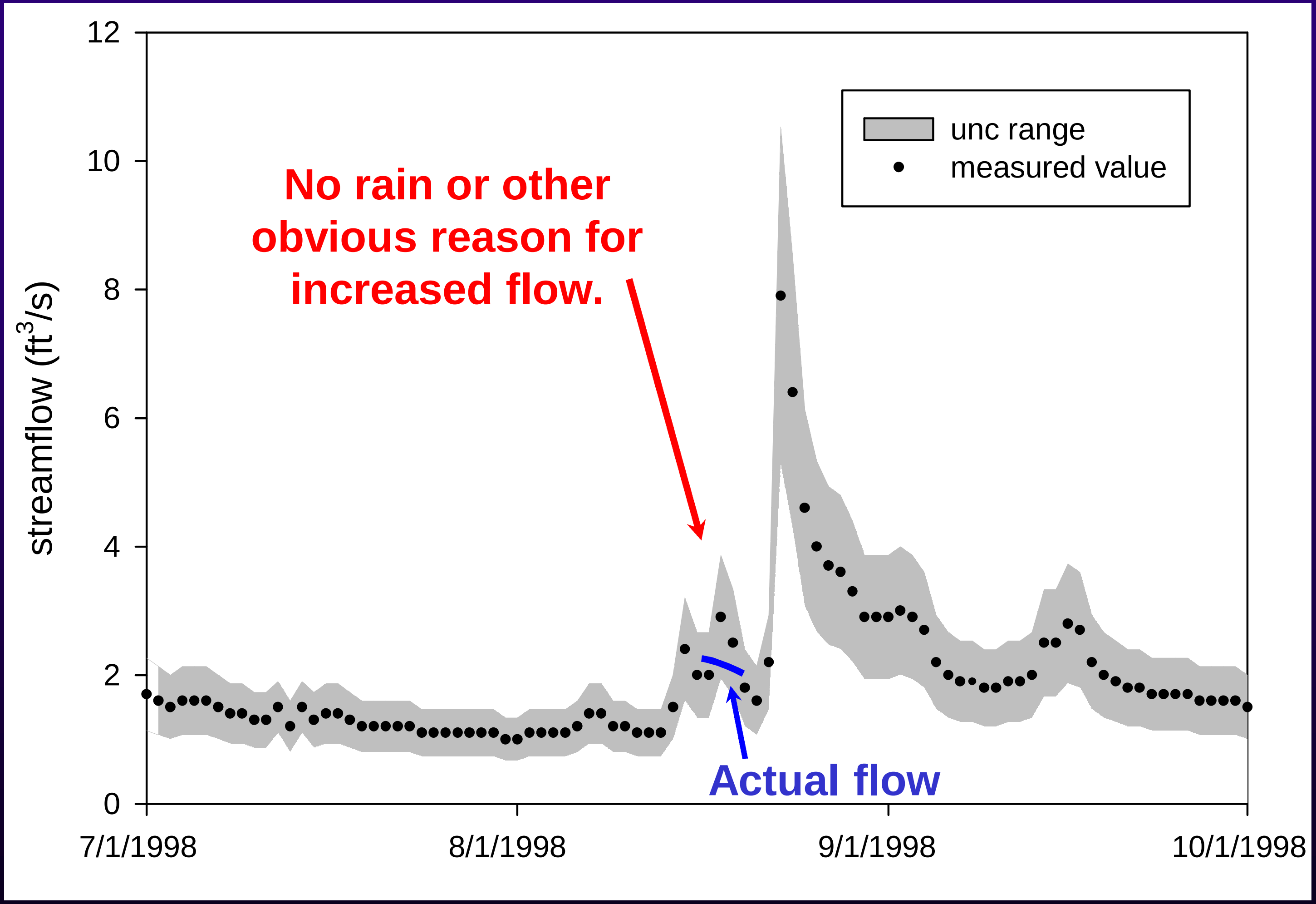
- **Difficulties:**
  - **No simple “click a button” method (hopefully soon).**

- **Benefits:**
  - **Appropriately share burden with “data providers.”**
  - **Conduct more realistic evaluations of model performance.**
  - **Help prevent “over fitting.”**
  - **Allow modelers to focus on model deficiencies.**
  - **More accurately communicate model performance**
    - **stakeholders, policy makers, regulators.**

Model Evaluation



Model Evaluation



Conclusions

- Historically, uncertainty in measured H/WQ data was rarely estimated and included in:
  - Research and monitoring
  - Data reporting
  - Regulation and policy
  - Model evaluation

- However, the environmental and socio-economic ramifications of decisions based on H/WQ data are too great for the inherent uncertainty to continue to be ignored.

Any Questions??

Daren Harmel
(254) 770-6521
daren.harmel@ars.usda.gov

www.ars.usda.gov/spa/hydro-collection